

HIGH STRENGTH GLASS-CERAMIC CONTAINING APATITE AND ALKALINE EARTH METAL SILICATE CRYSTALS AND PROCESS FOR PRODUCING THE SAME

FIELD OF THE INVENTION

The present invention relates to a high strength glass-ceramic containing apatite crystals which is useful as an implant material such as an artificial dental root and an artificial bone, and a process for producing the glass-ceramic.

BACKGROUND OF THE INVENTION

In recent years, an artificial material such as an artificial dental root or an artificial bone has been used as a substitute for a dental root or bone. Artificial materials which have heretofore been used for this purpose are anti-corrosive alloys such as a stainless steel and a cobalt/chromium alloy, and polymer such as polymethyl methacrylate and high density polyethylene. These materials, however, have a problem in that when those are used for a long period of time, metallic ions or monomers tend to elute in a living body and, therefore, those are sometimes harmful to a human body. On the other hand, a ceramic material generally exhibits an excellent biocompatibility to a living body and is stable in a living body. It has now received increasing attention as an artificial material.

One of such ceramic materials is single crystalline or polycrystalline alumina. This material is characterized by having a very high strength. The alumina ceramic, however, does not form any chemical bonding with a bone. To fix the alumina ceramic in a living body, therefore, a procedure should be employed in which the alumina ceramic itself is screwed or bored and physically fixed inside a bone. In this case, if the shape of the material is unsuitable, a stress sometimes concentrates in one part of the bone or material, resulting in the absorption of the bone and the formation of collagen fibers in the interface between the bone and the material. This makes loose the fixed part of the material or causes the material to come apart. In order to overcome the above problem, investigations have recently been made to develop ceramics which can form a chemical bonding with a bone and be firmly fixed inside the bone.

Typical examples of such ceramics are a sintered body of hydroxy-apatite, a $\text{Na}_2\text{O}-\text{CaO}-\text{P}_2\text{O}_5-\text{SiO}_2$ -based bioglass, and a glass-ceramic containing apatite crystals obtained by the precipitation of the apatite crystals from a $\text{Na}_2\text{O}-\text{K}_2\text{O}-\text{MgO}-\text{CaO}-\text{P}_2\text{O}_5-\text{SiO}_2$ -based glass. Hydroxy apatite crystals, however, are converted into tricalcium phosphate when sintered at high temperatures. Consequently, it is difficult to produce a sintered hydroxy-apatite having a dense structure and a high strength. The bioglass and apatite-containing glass-ceramic have a disadvantage in that those can be utilized only in parts where only a small stress is applied, since its mechanical strength is low. In recent years, therefore, glass-ceramic has been developed which can form a chemical bonding with a bone and further has a relatively high strength.

Such a conventional glass-ceramic is produced by the following method: grinding $\text{MgO}-\text{CaO}-\text{P}_2\text{O}_5-\text{SiO}_2$ -based glass with a MgO content of 7 wt% or less to 200 mesh or less powders, compression molding the glass powders and then heat treating the molding in the sintering temperature range of the glass powders and sub-

sequently in the temperature range where apatite and wollastonite crystals are formed. The thus-obtained glass-ceramic has a bending strength of from 1,200 to 1,400 kg/cm^2 . Of conventional materials forming a chemical bonding with a bone, the glass-ceramic has the highest strength. In this glass-ceramic, however, since the sintering temperature range of the glass powders is close to the crystal-precipitation temperature range, crystallization proceeds before air bubbles disappear by sintering. For this reason, it is difficult to produce the dense glass-ceramic having a high strength in every time. Thus, the above glass-ceramic has a disadvantage in that the strength varies depending on the production lot. Furthermore, when the glass-ceramic is used as an artificial dental root, it is desired to have a higher mechanical strength.

A glass-ceramic containing apatite crystals and alkaline earth metal silicate crystals such as diopside crystal, forsterite crystal and akermanite crystal is also known. This glass-ceramic is obtained by grinding a $\text{MgO}-\text{CaO}-\text{SiO}_2-\text{P}_2\text{O}_5$ -based glass with the MgO content of 8 wt% or more to 200 mesh or less powders, molding the glass powders, heat treating the molding in the sintering temperature range of the glass powders (750° to 880°C.) and then heat treating the molding in the temperature range where apatite crystals ($\text{Ca}_{10}(\text{PO}_4)_6\text{O}$) and alkaline earth metal silicate crystals such as diopside ($\text{MgO} \cdot \text{CaO} \cdot 2\text{SiO}_2$), forsterite ($2\text{MgO} \cdot \text{SiO}_2$) and akermanite ($2\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$) (830° to 1150°C.) are formed.

In this glass-ceramic, the apatite crystals act to improve the affinity with a living body and the alkaline earth metal silicate crystals act to increase the mechanical strength of the glass-ceramic. Therefore in order to obtain a glass-ceramic having a good affinity with a living body and a high mechanical strength, it is required for the glass-ceramic to contain the apatite crystals and alkaline earth metal silicate crystals as much as possible. However, in the conventional glass-ceramic of this type, if the heat treatment is conducted at high temperatures in order to increase the amount of alkaline earth metal silicate crystals formed, the apatite crystals which have been previously precipitated tend to decrease. Thus, those conventional glass-ceramic have the disadvantage in that if the amount of alkaline earth metal silicate crystals precipitated is increased thereby improving the mechanical strength, the apatite crystals decrease, resulting in lowering the affinity with a living body.

SUMMARY OF THE INVENTION

The present invention is intended to overcome the problems in the conventional glass-ceramic.

One object of the present invention is to provide a glass-ceramic which contains apatite crystals exhibiting an excellent affinity with a living body and has a high strength.

Another object of the present invention is to provide a process for producing the glass-ceramic.

The glass-ceramic of the present invention contains large amounts of apatite ($\text{Ca}_{10}(\text{PO}_4)_6\text{O}$) and at least one alkaline earth metal silicate crystals selected from the group consisting of diopside ($\text{MgO} \cdot \text{CaO} \cdot 2\text{SiO}_2$), forsterite ($2\text{MgO} \cdot \text{SiO}_2$) and akermanite ($2\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$) which are uniformly dispersed in the glass, and has a composition comprising, in % by weight, 8 to 34% MgO ;